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Spatial distribution of the plum scale insect, *Parlatoria oleae* (Colvee) (Hemiptera: Diaspididae) infesting mango trees in Egypt

Moustafa M.S. Bakry

Scale Insects and Mealybugs Research Dept., Plant Protection Research Institute, A.R.C, Dokii, Giza, Egypt.

Abstract— *The aim of the present study was to examine the spatial distribution for monitoring populations of Parlatoria oleae (Colvee) (Hemiptera: Diaspididae) infesting mango trees during two successive years (2016–2018) in Luxor Governorate, Egypt. The obtained results showed that insect population of P. oleae occurred on mango trees all the year round and has three peaks of seasonal activity per year, which was recorded in October, April and July during the first year (2016/2017) and through in November, April and July during the second year (2017/2018). Data were analyzed using twenty one distribution indices. All indices of distribution indicated significant aggregation behaviour in each year, except, the K values of the negative binomial distribution of the total P. oleae population ranged about 15-17 for each year during the two successive years, indicating random behavior. The results of this research can be used to draft monitoring methods for this pest and establishing IPM strategies for P. oleae.*

Keywords*— *Parlatoria oleae, population density, distribution patterns, directional preference, mango trees.

I. INTRODUCTION

In Egypt, mango trees (*Mangifera indica* L.) are subjected to infestation by several different pests. Among these pests, the plum scale insect, *Parlatoria oleae* is considered one of the most destructive pests of mango trees (**Bakr *et al*., 2009**). This pest species injures the mango tree shoots, twigs, leaves, branches and fruits by sucking out plant sap with the its mouth parts, subsequently causing deformations, defoliation, drying up of young twigs, dieback, poor blossoming, death of twig by the action of the toxic saliva and so affecting the commercial value of fruits where it causes conspicuous pink blemishes around the feeding sites of the scales. A characteristic symptom of infestation by pest is the appearance and accumulation of its scales on attacked mango parts **(El-Amir, 2002 and Hassan *et al*., 2009)**.

As well, spatial distribution is one of the most characteristic properties of insect populations; in most cases it allows us to define them, and is a typical trait in insect populations and is an important characteristic of ecological communities **(Debouzie and Thioulouse, 1986).** No field sampling can be efficient without understanding the underlying spatial distribution **(Taylor, 1984).** An understanding of the spatial distribution *i.e.* (regular, random or aggregated) of populations provides useful information, not only for theoretical population biology but also for field monitoring programmes, especially sequential sampling **(Feng *et al*., 1993 and Binns *et al*., 2000).**

A knowledge of the spatial distribution of an insect is central to the design of a management programme, and is important in understanding the bioecology of species and forms the basis for developing a sampling protocol **(Wearing 1988; Binns *et al.* 2000 and Cho *et al.* 2001).** No information is available in the literature concerning the spatial distribution of *P. oleae*. Therefore, the objective of this study was to estimate its spatial distribution over a period of two successive years (2016/2017 and 2017/2018) at Esna district, Luxor Governorate, Egypt.

II. MATERIALS AND METHODS

This The present work was conducted on seedy Balady mango trees in private orchard of about five feddans, on 10 years-old at Esna district, Luxor Governorate from beginning of September, 2016 until mid of August, 2018, to estimate the

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spatial distribution of *P. oleae*. The selected orchard received the normal agricultural practices without application any chemical control measures before and during the period of study.

Ten mango trees of Balady variety similar in age and as uniform as possible in size, shape, height, vegetative growth were selected. Regular half-monthly samples were picked up to randomly from different directions and stratums of tree with rate of 40 leaves per tree. The samples were collected regularly and immediately transferred to laboratory in polyethylene bags for inspection using a stereo-microscope. Numbers of total alive insects on upper and lower surfaces of mango leaves were counted and recorded together opposite to each inspected date.

The monthly mean numbers of total population of *P. oleae* per mango leaf ± standard error (S.E.) was considered in this study to express the population size of pest. Data were analyzed using a randomized complete block design, with ten replicates. Means were compared according LSD test at significance levels of $P \leq 0.05$, using **(MSTATC Program software, 1980)**.

All sampling was conducted from 19200 leaves on 48 dates over a 2-year period, *i.e.* 10 trees × 4 directions × 10 leaves × 48 dates. Samples were frozen to preserve them for subsequent processing.

To study the spatial distribution of *P. oleae* among the sample units was determined using 21 indices of distribution.

Distribution indices:

Several estimates are based on sample means and variances, such as index of dispersion, clumping, crowding and Green's index **(Green 1966).**

- Mean ($\bar{X}$): the mean number of individuals as a general average per leaf during the whole year.

- Range of means of a population: The difference between the maximum mean number of a population and the minimum for the whole year was calculated by applying the following equation:

- Range of Density (R) = Population density maximum – Population density minimum during the whole year.

- Variance (S^2), standard deviation (S), standard error (SE) and median (Me) for samples were determined.

- Coefficient of variance (*C.V.*): To assess the fidelity of sampling, the coefficient of variation values for the studied years were compared.

$$C.V. = \frac{S}{\bar{X}} \times 100$$

Where, *S* is the standard deviation of the mean and $\bar{X}$ is the mean of population.

- Relative Variation (*R.V.*) is employed to compare the efficiency of various sampling methods **(Hillhouse and Pitre, 1974).** The relative variation for the studied years was calculated as follows:

$$R.V. = (SE / \bar{X}) \times 100$$

Where, *SE* is the standard error of the mean and $\bar{X}$ is the mean of population.

- Index of dispersion (I_D):

$$(I_{DM}) = (S^2 / \bar{X}) - 1$$

The index of dispersion is also known as the variance to-mean ratio. Dispersion of a population can be classified through a calculation of the variance-to-mean ratio; namely:

Diffusion coefficient:

$S^2/\bar{X} = 1$ random distribution, < 1 regular distribution, and > 1 aggregated distribution (where, S^2 = sample variance; $\bar{X}$ = mean of population).

- Index of Lewis (I_L):

Lewis index was also calculated as per the formula given hereunder to determine the dispersion of *P. oleae*

$$I_L = \sqrt{S^2 / \bar{X}}$$

The value of this index revealed >1 contagious; <1: regular and =1 random distribution.

- Cassie index (*Ca*):

$$Ca = (S^2 - \bar{X}) / \bar{X}^2$$

The spatial distribution pattern is aggregative, random and uniform when $Ca > 0$, $Ca = 0$ and $Ca < 0$, respectively **(Cassie 1962).**

- The *K* value of negative binomial distribution:

The parameter *k* of the negative binomial distribution is one measure of aggregation that can be used for insect species having clumped or aggregated spatial pattern. When *k* values are low and positive ($k < 2$), they indicate a highly aggregated population; *k* values ranging from 2 to 8 indicate moderate aggregation; and values higher than 8 ($k > 8$) indicate a random population **(Southwood 1995).** The *k* values were calculated by the moment's method **(Costa *et al.* 2010),** and given by:

$$K = \bar{X}^2 / (S^2 - \bar{X})$$

- Departure from a random distribution can be tested by calculating the index of dispersion (I_D), where, n: denotes the number of samples:

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$$I_D = (n-1)S^2 / \overline{X}$$

I_D is approximately distributed as x^2 with n-1 degrees of freedom. Values of I_D which fall outside a confidence interval bounded with n-1 degrees of freedom and selected probability levels of 0.95 and 0.05, for instance, would indicate a significant departure from a random distribution.

This index can be tested by Z value as follows:

$$Z = \sqrt{2I_D} - \sqrt{(2\nu - 1)}$$

$v = n - 1$

If $1.96 \geq Z \geq -1.96$, the spatial distribution would be random, but if $Z < -1.96$ or $Z > 1.96$, it would be uniform and aggregated, respectively **(Patil and Stiteler 1974).**

- Index of mean clumping (I_{DM}) **(David and Moore 1954):**

$$I_{DM} = \frac{s^2}{\overline{x}} - 1$$

The David and Moore index of clumping values increase with increasing aggregation. If the index value = 0, the distribution is random, positive value for negative binomial (aggregated) and negative value for positive binomial (regular).

- Lloyd's mean crowding ($\overset{*}{X}$):

Mean crowding ($\overset{*}{X}$) was proposed by Lloyd to indicate the possible effect of mutual interference or competition among individuals. Theoretically, mean crowding is the mean number of other individuals per individual in the same quadrate:

$$\overset{*}{X} = \overline{X} + [(S^2 / \overline{X}) - 1]$$

As an index, mean crowding is highly dependent upon both the degree of clumping and population density. To remove the effect of changes in density, Lloyd introduced the index of patchiness, expressed as the ratio of mean crowding to the mean. As with the variance-to-mean ratio, the index of patchiness is dependent upon quadrate size **(Lloyd, 1967).**

- Index of patchiness (I_P): is dependent upon quadrate size.

$$I_P = (\overset{*}{X} / \overline{X})$$

If IP = 1 random, < 1 regular and > 1 aggregated

- *Green's index* (*GI*):

$$GI = [(S^2 / \overline{X}) - 1]/(n-1)$$

This index is a modification of the index of cluster size that is independent of n **(Green, 1966).**

If GI > 0 or positive values are indicative of aggregation dispersion, GI < 0 or negative values indicative of uniformity or regular dispersion, and GI = 0 or negative values closer to 0 indicate randomness.

- To evaluate temporal changes in spatial pattern of *P. oleae* population during the studied years, an aggregation index (1/*k*) **(Southwood and Henderson 2000)** was used.

It was calculated by the formula of

$$1/k = (\overset{*}{X} / \overline{X}) - 1$$

where: 1/k is aggregation index or Cassie's index C and ($\overset{*}{X} / \overline{X}$) is Lloyd's patchiness index. The values of 1/*k* < 0, = 0, and > 0 represent regularity, randomness, and aggregation of the population in spatial pattern, respectively **(Feng and Nowierski 1992).**

All obtained data were depicted graphically by Microsoft Excel 2010.

III. RESULTS AND DISCUSSION

1- Seasonal activity of *P. oleae* on mango trees:

Results as represented in Table (1), showed that the mean total population of *P. oleae* per leaf through the whole year was 105.07 ± 2.54 and 119.78 ± 2.81 individuals over first and second years, respectively.

During the first year (2016/2017), the seasonal abundance of total population of insect was recorded. Three peaks of activity were observed in October, April and July when the mean population density was 151.39 ± 2.15, 106.46 ± 2.28 and 136.59 ± 1.25 individuals per leaf, respectively.

A similar trend in the seasonal activity of the total population of *P. oleae* per leaf was observed during the second year (2017/2018). Three peaks of activity were occurred in November, April and July when the mean population density was 154.73 ± 2.83, 131.46 ± 2.88 and 147.19 ± 2.11 individuals per mango leaf, respectively.

As well as, the total population of insect through the second year was higher in comparison to the first year of study. This might be due to the influence of favourable environmental factors. Also, the maximum values of insect population were recorded in October month during the first year and in November month through the second year. When crawlers emerged after the egg laying period, their population decreased during several months due to mortality of nymphs stage in the winter. In contrary, the least population density of total population of *P. oleae* were recorded during February during the two years of study, which may be attributed to the

high relative humidity with the gradual decrease in temperature and dormancy of the trees during winter time which is expected to effect dramatically the insect behavior and on rate of growth and infestation. **Dent (1991)** stated that the seasonal phenology of insect numbers, the number of generations, and the level of insect abundance at any location are influenced by the environmental factors at that location.

Also, the obtained results revealed that the months of autumn and summer were the most favorable seasons for *P. oleae* activity, multiplication and distribution through the two consecutive years. As well, the maximum values of log (mean of population) and averages of crowding of the total population of the pest were recorded during the autumn months in the two successive years, (Table, 1).

From the previously mentioned results, it could concluded that insect population occurred on mango trees all the year round and has three peaks of seasonal activity per year for total population of *P. oleae*. These results were coincided with those obtained by **El-Hakim and Helmy (1982)** in Egypt, mentioned that *P. oleae* had three peaks in Cairo and Fayoum, and two peaks in Alexandria on olive trees. **Asfoor (1997),** in Qalyobia Governorate, Egypt, reported that three generations of *P. oleae* annually on pear trees, but only two generations on plum, pear and apple trees. Also, recorded three annual peaks on Hollywood plum, maribosa plum, apricot and peach these peaks occurred in May, August and October. **Ezz (1997)** in Egypt, indicated three generations on four deciduous trees, the first generation appeared on first May, the second appeared on first August and the third generation appeared on first October.

2- Sampling programme

The *R.V.* (%) for the primary sampling data of *P. oleae* indicated that the total population density was 2.41, 2.35 and 1.73% during the first and second years, and for the two years combined, respectively (Table, 2). However, with different insect species and different hosts, **Naeimamini *et al.* (2014)** stated that the *R.V.* of the primary sampling data of different stages of *Pulvinaria floccifera* (Westwood) (Coccomorpha: Coccidae) was less than 25%, which was acceptable. **Bakry (2018)** reported that the *R.V.* of the primary sampling data of the total populations of *Waxiella mimosae* (Signoret) (Coccomorpha: Coccidae) on sunt trees ranged from 8.52% to 19.79% and were recorded during all seasons of the year, as well as over the entire year.

3- Estimate the spatial distribution of *P. oleae*.

The results in Table (2) showed that the spatial distribution among the sample units was determined by 21 indices of distribution. The results of distribution by using the variance of *P. oleae* population on mango trees more than general average of total population density by pest and thus, the variance to mean ratio S^2/m) more than one indicating that the spatial distribution of total population of *P. oleae* is aggregation distribution over the entire year during the two successive years.

The index of Lewis of total live stages of the pest was significantly greater than one indicating an contagious dispersion. Similarly conclusions can be made from the results of Cassie index (*Ca*). Total population of the pest distribution was greater than zero, which indicated that *P. oleae* on mango trees has an aggregation distribution.

On contrary, the *K* values of the negative binomial distribution of the total *P. oleae* population ranged about 15-17 for each year during the two successive years, indicating random distribution.

The index values of mean clumping (*IDM*) was positive for the negative binomial. Z-test values were greater than 1.96. The index of patchiness was greater than one and Green's index (*GI*) was greater than zero and its values were positive. All these indices showed an aggregation distribution for the total population of *P. oleae* in each year and during the two cumulative years. The temporal changes in the spatial distribution pattern of *P. oleae* population during the each year were evaluated using *1/k* (aggregation index). The value was greater than Zero indicating an aggregated pattern, which became more dispersed with time.

It was concluded that, the spatial distribution for the total population of *P. oleae* using twenty-one indices of distribution, indicated an aggregation distribution in each year during the two successive years, except, the K values of the negative binomial distribution of the total *P. oleae* population ranged about 15 to17 for each year during the two successive years, indicating random behavior. However, there is no report in literature regarding the distribution pattern of *P. oleae*. However, with different insect species and different hosts, **Chellappan *et al*. (2013)** reported that the value of mean crowding increased with an increase in mean population density of *Paracoccus marginatus* (Hemiptera: Pseudococcidae).

Li *et al.* (2017) recorded that the K value of the negative binomial distribution, aggregation index, and Cassie index (Ca) are all higher than zero during May. This would indicate that *Parapoynx crisonalis* (Lepidoptera: Crambidae) larvae on were in an aggregation distribution. **Bala and Kumar (2018)** recorded that the value of Lewis index for all the sampling

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dates of the bug, *Chauliops fallax* (Hemiptera: Malcidae) population on soybean were also found to be more than one indicating that the distribution of the bug population was aggregated. **Bakry (2018)** in Egypt, studied that the spatial distribution of *W. mimosae* on sunt trees using fourteen indices of dispersion, who found that the all models of dispersion indices, exhibited an aggregated distribution and follows a negative binomial distribution pattern for all alive different stages and total population of *W. mimosae* in all seasons of the year and on the over year during the two years of study (2016 to 2018).

The above mentioned results could have important implications in monitoring methods for this pest and establishing IPM strategies for *P. oleae*.

Table.1: Monthly mean numbers, variance and mean of crowding $\overset{*}{X}$ of P. oleae total population on mango tree at Esna district, Luxor Governorate during the two successive years of (2016/2017 and 2017/2018):

Season	Date of inspection	First year of (2016/2017)					Second year of (2017/2018)				
		Mean number of individuals per leaf ± S.E.	Variance	log mean	log variance	$\overset{*}{X}$	Mean number of individuals per leaf ± S.E.	Variance	log mean	log variance	$\overset{*}{X}$
Autumn	September	120.60 ± 2.63	69.05	2.08	1.84	120.17	125.60 ± 2.52	63.57	2.10	1.80	125.10
	October	151.39 ± 2.15	46.28	2.18	1.67	150.69	146.07 ± 1.92	36.83	2.16	1.57	145.32
	November	133.12 ± 2.55	65.23	2.12	1.81	132.61	154.73 ± 2.83	80.26	2.19	1.90	154.25
Average		**135.03 ± 2.72**	**221.35**	**2.13**	**2.35**	**135.67**	**142.13 ± 2.65**	**210.41**	**2.15**	**2.32**	**142.61**
Winter	December	95.43 ± 1.30	17.01	1.98	1.23	94.61	147.45 ± 2.04	41.43	2.17	1.62	146.73
	January	69.05 ± 0.94	8.78	1.84	0.94	68.18	69.52 ± 0.47	2.23	1.84	0.35	68.56
	February	61.14 ± 0.78	6.06	1.79	0.78	60.24	60.48 ± 1.50	22.63	1.78	1.35	59.86
Average		**75.21 ± 2.78**	**232.24**	**1.88**	**2.37**	**77.30**	**92.49 ± 7.30**	**1597.30**	**1.97**	**3.20**	**108.76**
Spring	March	71.60 ± 1.65	27.23	1.85	1.44	70.98	112.52 ± 2.65	70.03	2.05	1.85	112.14
	April	106.46 ± 2.28	51.93	2.03	1.72	105.95	131.46 ± 2.88	82.75	2.12	1.92	131.09
	May	96.50 ± 1.79	32.13	1.98	1.51	95.83	103.89 ± 1.49	22.32	2.02	1.35	103.11
Average		**91.52 ± 2.93**	**256.84**	**1.96**	**2.41**	**93.33**	**115.96 ± 2.53**	**191.50**	**2.06**	**2.28**	**116.61**
Summer	June	117.80 ± 0.69	4.76	2.07	0.68	116.84	139.80 ± 0.87	7.49	2.15	0.87	138.86
	July	136.59 ± 1.25	15.52	2.14	1.19	135.71	147.19 ± 2.11	44.71	2.17	1.65	146.49
	August	101.20 ± 1.39	19.27	2.01	1.28	100.39	98.64 ± 2.31	53.25	1.99	1.73	98.18
Average		**118.53 ± 2.87**	**228.54**	**2.07**	**2.36**	**119.46**	**128.54 ± 4.10**	**504.71**	**2.11**	**2.70**	**131.47**
General average		105.07 ± 2.54	771.94	2.02	2.89	111.42	119.78 ± 2.81	946.99	2.08	2.98	126.69

Table.2: Estimated parameters for spatial distribution of total population of P. oleae infesting mango trees during the two successive years (2016/2017 and 2017/2018).

Parameters	First year (2016/2017)	Second year (2017/2018)	Combined two years (2016-2018)
Max.	151.39	154.73	154.73
Min.	61.14	60.48	60.48
Mean	105.07	119.78	112.43
Range of mean	90.24	94.24	94.24
Median	103.83	128.53	115.16
S^2	771.94	946.99	910.16
S	27.78	30.77	30.17
SE	2.54	2.81	1.95
CV	26.44	25.69	26.83
RV	2.41	2.35	1.73
S^2/m	7.35	7.91	8.10
Lewis Index	2.71	2.81	2.85
Cassie index	0.06	0.06	0.06
K	16.56	17.34	15.84
I_D	874.26	940.82	1934.86
Z value	26.42	27.98	40.37
I_{DM}	6.35	6.91	7.10
X*	111.42	126.69	119.52
X*/m	1.06	1.06	1.06
GI	0.05	0.06	0.03
1/*k*	0.06	0.06	0.06

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